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INFLUENCE OF OVERBURDEN ON SOIL COALESCENCE

Oleh :
Uswah Hasanah[1)]

ABSTRAK

Pengamatan di lapangan menunjukkan bahwa agregat koalesen terlihat jelas berkembang dilapisan bawah zona penanaman selama musim tanam. Hal ini menunjukkan bahwa tekanan overburden meningkatkan tingkat kontak antar agregat tanah. Tanah dengan kandungan partikel bahan organik tinggi relatif resisten terhadap berkembangnya agregat koalesen. Penelitian ini dilaksanakan untuk mengevaluasi pengaruh bahan organik dan overburden, dengan cara meletakkan silinder logam yang memiliki berat berbeda (setara dengan tekanan static 0; 0,49; 1,47; dan 2,47 kPa) pada bagian atas agregat tanah kering (diameter 0,5-2 mm) dengan kandungan bahan organic yang berbeda. Agregat tanah kemudian dibasahi pada kondisi hamper jenuh selama 24 jam kemudian didrainase dengan menggunakan lempeng keramik pada hisapan 100 kPa selama 1 minggu. Kerapatan isi, tahanan penetrometer dan kekuatan tarik diukur ketika sampel tanah dikeluarkan dari lempeng keramik. Semua parameter yang diamati meningkat dengan bertambahnya tekanan overburden pada tanah dengan bahan organik rendah, tetapi tidak pada tanah dengan bahan organik tinggi.

Kata kunci: Koalesen, overburden, bahan organic, hisapan, kerapatan isi, tahanan penetrometers, kekuatan tarik

I. INTRODUCTION

An open soil structure inevitably consolidates after tillage due to overburden pressure (Koolen and Kuipers, 1989) and its bulk density increases once irrigation commences (Ghavami *et al*., 1974). Even in un-tilled soils, bulk densities consistently increase with depth (Cannel, 1985). Field observations have indicated that aggregate coalescence is first expressed at the bottom of the seedbed and develops progressively upward to the soil surface during the growing season (e.g. B. Cockroft and C.D. Grant pers. Comm.) This suggests that overburden pressures may enhance aggregate coalescence by increasing the degree of inter-aggregate contact.

The purpose of this experiment was to determine the effects of overburden on coalescence of water stable soil aggregates.

II. MATERIALS AND METHODS

Five soils including cultivated and virgin Shepparton soils, cultivated and virgin Cornella soils and virgin Wiesenboden were used in this experiment. Aggregate fractions of 0.5-2 mm were packed into cylindrical rings (5 cm high and 4.77 cm i.d.) with thin mesh at the base. Perforated brass cylinders of 4.5 cm diameter and of 4 various weights (0, 80, 240, and 400 g) were set on top of the soil cores. Based on assumptions of a dry bulk density of 1.2 g cm^{-3} and of a volumetric water content of 0.3 cm cm^{-3}, these weights simulated reasonable static load pressures of 0, 0.49, 1.47 and 2.47 kPa in the root zone which are equivalent to depths of 0, 3.4, 10.1 and 16.8 cm. The soil cores were subjected to wetting near saturation for 24 hours and then drained at 100 kPa suction (Chapter 2). In the following text, the overburden pressures will be referred as 0, 0.5, 1.5 and 2.5 kPa.

Soil resistance was measured by recording the force exerted by a cone penetrometer of 2 mm diameter with a recessed shaft and a total cone angle of 60^0 moving at 0.3 mm/minute as it entered the soil core resting on a digital top-loading balance. This was conducted at 5 positions in each core. At each position the load (g) was recorded at 10 second increments. Balance readings were converted to force (N) and then penetration resistance was calculated as the force divided by the area of the cone-base (Zhang *et al*., 2001).

Soil tensile strength was measured according to the indirect method known as the Brazilian core test (Dexter & Kroesbergen,

1) Staf Pengajar pada Program Studi Ilmu Tanah Fakultas Pertanian Universitas Tadulako, Palu

1985). The tensile strength, Y, (kPa) was calculated from:

$$Y = 2F/ \pi dL,$$

Where F is the load applied at the point of failure; d is the diameter of the soil core; L is the length of the soil core. Prior to tensile strength measurements, cores were air-dried slowly at room temperature (20^{0}C) until their weights were relatively constant.

Bulk density was obtained prior to penetrometer measurements as the ratio of the soil oven dry weight to its volume at 100 kPa suction.

For each soil, a completely randomised design was used with three replicates. The treatments were the suctions imposed during wetting and draining. Data was analysed using a Genstat 5 program (Genstat 5 Committee, 1987).

III. RESULTS AND DISCUSSION

3.1. Soil Penetrometer Resistance

Figure 1 shows penetrometer resistance of the soils studied as a function of soil depth with various overburden pressures.

As might be expected, the penetration resistance of the Shepparton soil increased in approximate proportion to the applied overburden, particularly for the cultivated soil. At 25 mm depth, the resistance increased from 253 to 586 kPa when the overburden pressure increased from zero to 2.5 kPa. For the virgin sample, soil resistance also increased with applied overburden, but much less so than in the cultivated soil. For example, the profile of soil resistance for the un-burdened cultivated soil was similar to that of the virgin soil with the largest overburden pressure (2.5 kPa).

For the Cornella soil, the effects of overburden were enhanced with depth, particularly in the cultivated soil, where the soil resistance (under 2.5 kPa pressure) tripled from ~300 kPa at the top of the core to over 1000 kPa at the bottom. By contrast, the virgin soil showed very little change with depth in the soil core, such that under an overburden pressure of 2.5 kPa the soil resistance ranged from ~200 kPa at the top of the core to only ~400 kPa at the bottom. That is, the profiles of penetration resistance in the virgin soil were generally more uniform than in the cultivated soil.

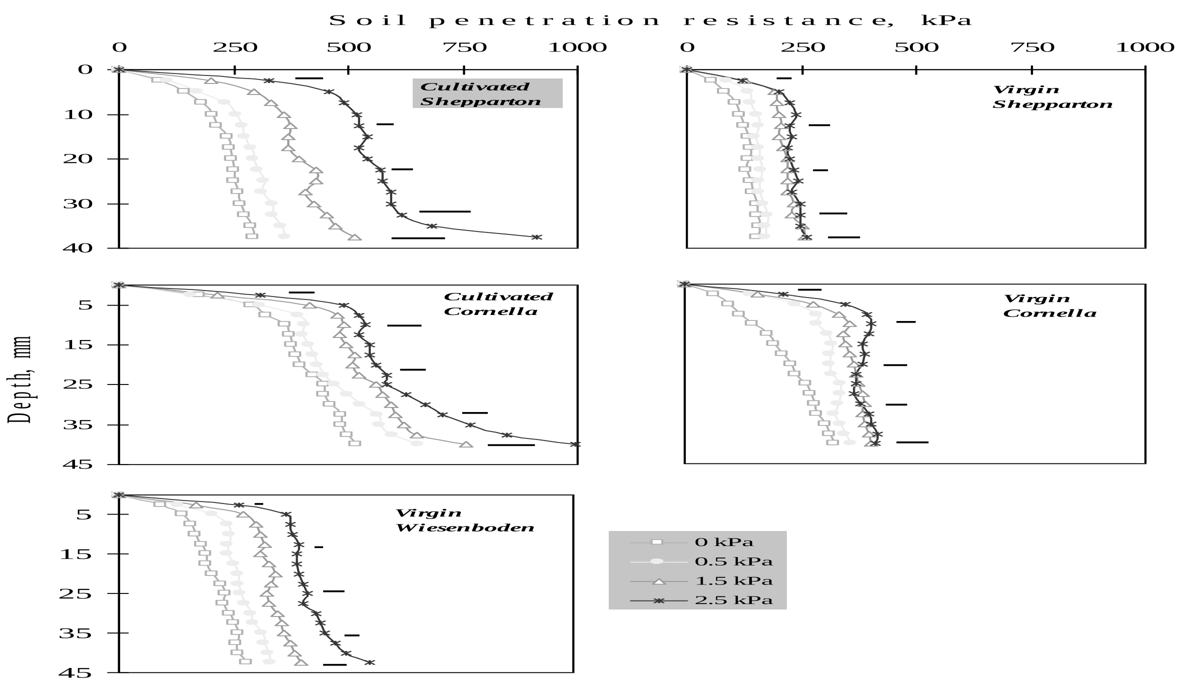

Figure 1. The Effect of Overburden on Penetration Resistance at 100 kPa
Horizontal bars indicate least significant differences at P<0.05

The penetration resistance of Wiesenboden consistently increased with soil depth as well as overburden. Soil resistance increased in approximate proportion to the overburden applied.

At 25 mm, the penetration resistance increased from 238 to 417 kPa when the overburden pressure increased from zero to 2.5 kPa.

3.2. Bulk Density

Figure 2 shows the bulk density of the soils studied. Increasing overburden pressures significantly ($P<0.05$) affected the bulk density of the cultivated Shepparton soil although the increase appeared to be small. It increased from ~1.01 g cm^{-3} up to ~1.14 g cm^{-3}. The effect of overburden on the bulk density of the virgin soil was not statistically significant at $P<0.05$ (from ~0.67 g cm^{-3} up to ~0.69 g cm^{-3}).

The effect of overburden on the bulk density of the Cornella soils was statistically significant at $P<0.05$. Bulk densities generally increased with increasing overburden and the rates of the increase were approximately the same for both virgin and cultivated soils (~0.89 up to 0.94 g cm^{-3} for cultivated, and ~0.61 up to 0.65 g cm^{-3} for virgin) as the overburden pressures increased from 0 to 2.5 kPa.

3.3. Water Content

Table 1 shows water contents for the various overburden pressures. The effect of overburden on the water contents of the two Shepparton soils (cultivated and virgin), the virgin Cornella and the Wiesenboden was not statistically significant. The water contents increased significantly with increasing overburden only in the cultivated Cornella soil.

Table 1. Soil Water Contents (G G^{-1}) at 100 kPa Suction as Affected by Overburden

Overburden (kPa)	Shepparton		Cornella		Wiesenboden
	Cultivated	Virgin	Cultivated	Virgin	Virgin
0	0.109^a	0.205^a	0.311^a	0.298^a	0.392^a
0.5	0.112^a	0.209^a	0.331^b	0.317^a	0.396^a
1.5	0.106^a	0.196^a	0.330^b	0.325^a	0.399^a
2.5	0.107^a	0.204^a	0.337^b	0.328^a	0.381^a
LSD	na	na	0.013	na	na

In each column, different letters indicate significant differences at $P<0.05$ na, not applicable

increa
overb

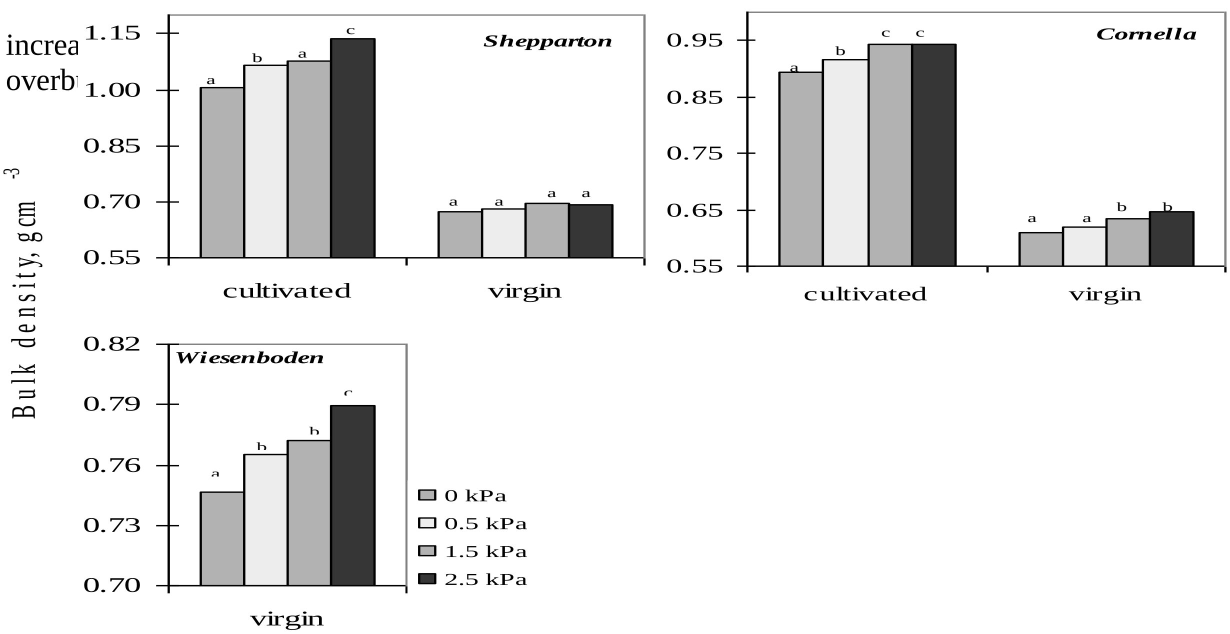

Figure 2. The Effect of Overburden on Bulk Density at 100 kPa Suction
Horizontal bars indicate least significant differences at P<0,05

3.4. Tensile Strength

Figure 3 presents the tensile strength as affected by overburden. Overburden did not affect the tensile strength of the virgin Shepparton which had zero tensile strength at all levels of overburden. The effect, however, was found to be significant in the cultivated soil. The tensile strength was relatively constant at overburden pressures less than 1.5 kPa but then increased considerably at 2.5 kPa.

Overburden significantly affected the tensile strength of both the cultivated and virgin Cornella soils, although the absolute magnitude of tensile strength was smaller for the virgin soil than for its cultivated counterpart. In the cultivated soil, the tensile strength increased markedly from 19 to 46 kPa as the overburden pressure increased from 0 to 2.5 kPa while in the virgin soil, the increase was from 0.2 to 2 kPa.

The tensile strength of Wiesenboden was also significantly affected by the overburden. The tensile strength consistently increased with overburden in which the largest increase occurred when the overburden increased from 1.5 to 2.5 kPa.

All soils showed significant increases in penetration resistance and bulk density as a result of increasing overburden pressures, while for the water content, only the cultivated Cornella clay showed a significant increase. The effects of overburden on penetration resistance appeared to be much greater than on bulk density. Penetration resistance increased in the range 19 - 125% for the Shepparton cultivated soil, 11 - 39% for the cultivated Cornella soil and 19 - 75% for the Wiesenboden with increasing overburden. Bulk density by contrast increased by only 6 - 13%, 2 - 5%, and 2 - 5%, respectively. Greacen (1981) found that a red brown earth (similar to Shepparton soil) had increases in bulk density of 31 - 55% which corresponded to increases in penetration resistance of 300 - 350%.

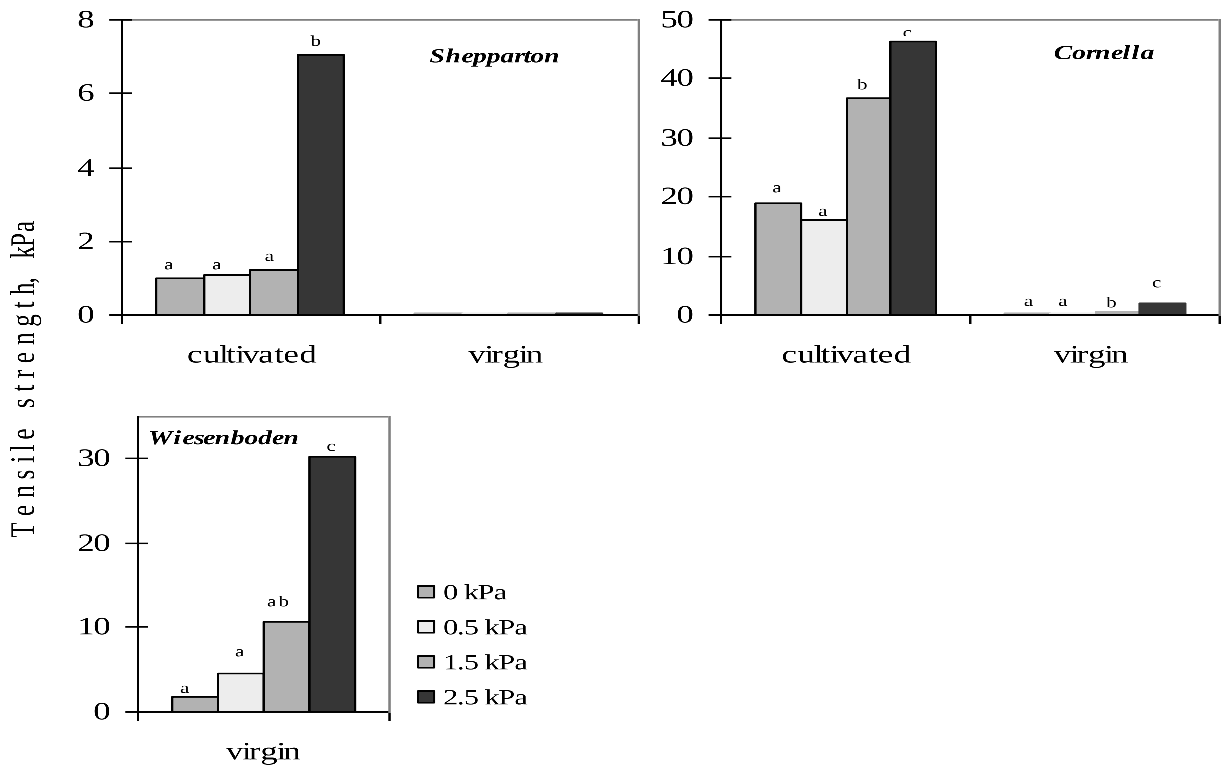

Figure 3. The Effect of Overburden on Tensile Strength of The Air Dried Soils

The rate of increase in soil resistance with depth was greater for the cultivated than for the virgin soils suggesting that organic matter has some protective role. For example, the effect of a 0.5 kPa overburden pressure on the penetration resistance profile for virgin Shepparton soil was relatively small, possibly suggesting that there may be a critical overburden pressure below which no effects on penetration resistance (soil structure) may occur in this soil

In the (swelling) cultivated Cornella the increase in the bulk density was associated with an increase in water content. It seems that more fine pores were created by increased overburden so that the degree of saturation in this soil increased.

The relative increases in the tensile strength appeared to be different for each soil. The increase in tensile strength of the cultivated Shepparton soil was significant only for the largest overburden pressure (2.5 kPa), suggesting that the low clay content of this soil lead to reduced aggregate coalescence until substantial pressures were reached. Furthermore, when this soil had higher organic matter content (virgin Shepparton), aggregate coalescence appeared to be completely preventable as zero tensile strength was evident at all overburden pressures. In the fine-textured soil (Cornella), even the virgin soil showed development of aggregate coalescence with increasing overburden, although the values were smaller than that of its cultivated counterpart.

IV. CONCLUSIONS

Soil bulk density and soil resistance increased with increasing overburden for most of the soils examined in this work. The virgin soils exhibited greater resistance to structural changes under overburden than did the cultivated soils regardless of whether the soil was swelling or non-swelling. Where densification occurred under increasing loads, the degree of saturation increased, but when densification was resisted (in virgin soils), very little change in water content occurred. Organic matter provided considerable resilience under applied overburdens. The implications appeared from this work for soil management in the field is that maintaining relatively high organic matter content in soil into larger depths could reduce the risk of aggregate coalescence development due to overburden pressure.

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